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(54) Combustion turbine blade with varying coating.

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Description

The present invention relates to a turbine blade, for a land-based or marine combustion turbine, and in particular to turbine blades provided with coatings for protecting such blades.

Land-based or marine-type combustion turbines present difficult problems of blade materials. Near the tip of the blades, the temperatures are often 1700°F or more. Down near the base of the blade (near the shaft), temperatures are much cooler, for example, approximately 1000°F. In addition, such turbines are commonly operated with fuels containing corrosive impurities such as sulfur and vanadium. Further, corrosion-causing compounds such as sea salt or fertilizer are often ingested in with the air drawn in by the turbine compressor. Such problems are significantly worse with land-based and marine combustion turbines are compared to aircraft (aircraft turbines are operated with cleaner fuel and significantly less contaminated air).

Reference is made to GB—A—696715 which discloses the use of a powdery material formed of carbides, borides and silicides to provide an alloy resistant to scale formation and where the composition of the alloy varies continuously towards the tip of the blade or where the blade can be subdivided into several zones, which are individually of uniform composition. FR—A—2367833 discloses a corrosion resistant envelope constituted by the elements Ni, Co and Fe where the material of the corrosion resistant layer may vary in composition.

The range of temperatures of many gas turbine blades (as used herein, the term "blades" is used to mean turbine components having airfoil portions whether rotating or stationary, e.g. including the stationary parts which are sometimes called "vanes") generally exceeds the range of effectiveness of any single type of coating. This is in part due to the chemical/thermal stability of a coating in the various deleterious corrosive environments and partly due to the physical/mechanical properties of the coating itself. This invention enables the use of a multiple composite coating system that enables the designer to maximise coating capabilities without the usual compromises (especially with regard to reduced physical/mechanical properties above or below the ductile/brittle transition temperature which are inherent to any given coating composition.

The invention consists in a coated turbine rotor blade or nozzle guide vane for land-based or marine combustion turbines, said blade or vane having a hot end at least a portion of which is designed to operate at a temperature in excess of 1500°F (816°C) a cooler end portion at least a portion of which is designed to operate at a temperature of less than 1250°F (677°C) and an intermediate portion at least a portion of which is designed to operate at between 1250°F and 1500°F (677°C and 816°C), characterized in that said blade or vane comprises a hot end portion coated with a low creep-type coating which is resistant to high temperature oxidation, a cooler end portion coated with a ductible-type coating which is resistant to sulfide corrosion, and an intermediate portion which is coated with a mixture of said hot end coating and said cooler end coating.

Advantageously, it is to be noted that not only must the hotter portion be protected against high temperature oxidation type corrosion, but that the coating on this portion of the blade must be creep resistant. Conversely, the cooler temperature of the blade (especially those portions less than about 1250°F (722°C) must be protected against sulfide-type corrosion and must have high coating ductility to prevent crack propagation. Further, it has been found that an intermediate zone, which is a mixture of the two coatings, must be used in order to prevent problems such as abrupt chemical discontinuities in the coating or stress concentrations. Preferably, the coatings are applied by plasma spraying and the intermediate portion is a grated coating giving a smooth transition from the hot end coating to the cooler end coating.

The invention will now be described, by way of example, with reference to the following drawings in which:

Figure 1 is an elevation of a blade;

Figure 2 is a blade elevation showing three coating zones;

Figure 3 shows system for applying the coatings of this invention; and

Figure 4 is a graph of typical ductilities for coatings and superalloy base materials at various temperatures.

Referring to the drawings, Figure 1 shows a blade with a portion designated 10 as the hot end part, and a cooler end portion 12.

A gas turbine blade may have an operating temperature profile ranging from about 1000°F at the base of the gas path surface to nearly 1800°F at the outermost tip region. Because the corrosion causing species and compounds are stable only through certain temperature ranges, application of a singular coating system has inherent limitations. A coating system which is most effective in preventing low temperature class II type corrosion in the range of 1000°F to 1450°F (538°C to 788°C), for example, could be applied through the lower portion of the airfoil and a high temperature corrosion resistant composition applied to the upper portion (away from the center axis) of the airfoil where the blade temperatures are highest.

At the hot end of blade the inherent ductility of most coating systems currently employed for environmental protection is generally equal to or greater than that of the base alloy to which it is applied. Premature failure of the blade due to brittle coating behavior and crack initiation is therefore not likely. Consequently, the coating that exhibits the best environmental protection may be utilized.

At the cooler and 12 of the blade (generally here the end towards the 1000°F (538°C) temperature),

it has been discovered that unusually high ductility for these temperatures is required in addition to resistance to low temperature sulfide-type corrosion. As used herein, the term "ductile-type coating" means coatings which have a ductility of greater than or equal to that of the base metal at a given operating temperature. The correlation of coating and base metal ductility can be demonstrated in Figure 4.

Figure 2 shows three zones of coating, with a hot-end coating 14 at the top and a cooler-end coating 16 at the bottom, with a transition zone 18 being coated with a mixture of hot-end coating and cooler-end coating. This transition zone 18 eliminates a sharp transition between the hot end coating and the cooler end coating. As a variation in the coating in an abrupt manner would result in poor thermal/mechanical properties and the possibility of uncoated areas resulting from less than perfect alignment, the transition needs to be gradual. Generally, this transition zone 18 will be at least 0.5 inch (12.77 mm) in height.

Preferably, the coating is applied by plasma spray. If pack cementation techniques were used, additional handling would be required and masking would present difficulties with little or no control over interdiffusion between masked areas. It would be very difficult, therefore, to control the transition from one coating chemistry to the adjacent coating chemistry.

Although any type of plasma spray could be used, a non-oxidising plasma spray system is thought to be the most practical. As most such coatings require an inert atmosphere or vacuum, such plasma spraying could, for example, be done with an argon floor or low pressure plasma spray.

Although the transition zone could be formed by applying the coating compositions one at a time (e.g. by applying the hot-end coating with its thickness tapering from full thickness at the top end of the transition zone down to essentially zero thickness at the lower end of the transition zone and then applying the cooler-end coating with a maximum thickness at the lower transition zone and tapering down to near zero at the upper end of the transition zone; preferably followed by appropriate heat treatment), the coating is preferably applied by a system such as shown in Figure 3 where the transition zone 18 is accomplished by spraying a powder premixed by the hopper system. Thus, the hot end coating composition (designated "A") and the cooler end coating (designated "B") are loaded into separate hoppers 20, 22. As the plasma gum 24 traverses the blade airfoil (under programmed computive control to maintain coating thickness profile), the feeding mechanism of the powder hoppers containing A and B compositions can be programmed to deliver the proper powder or powder mixture to the mixing vessel 26 which in turn supplies the gun 24. As the plasma gun 24 moves down the airfoil, the composition is initially 100% A, then an A-rich mixture becoming richer and richer in B, then a B-rich mixture and finally a 100% B coating. Generally all three zones (14, 18, and 16) will have a height of at least ½ inch.

The specification of U.S. Patents Nos. 3,545,944 and 3,020,182 describe similar systems being used for different purposes.

It can be seen that a coating system similar to Figure 3 can be used to coat more than three zones. For example, if erosion (or corrosion or coating ductility) were a problem on some particular portion of the blade, a third hopper with a "C" type coating composition could be added to apply an erosion resistant coating (or extended corrosion or lower temperature ductility coating etc.) in this area (preferably using an additional transition zone).

It should be noted that prior-art single coatings can fail mechanically due to insufficient creep strength, but that this problem is generally in the high temperature regions, above the ductile/brittle coating transition temperature. Failures also can be caused by poor ductility below the brittle/ductile transition temperature of such a single coating. By using different coatings in the high temperature region and the cooler temperature region, a low temperature corrosion resistant coating with good low temperature ductility can be used on the lower portion of the blade airfoil. A high temperature corrosion resistant coating with good high temperature creep resistance is applied to the upper portion of the airfoil. Problems at the interface of the two regions are avoided by using the blended composition in the intermediate zone of the airfoil.

It is felt that current coating systems are compromises in an attempt to perform adequately over a wide range of conditions, and are not optimized for providing either the high temperature corrosion resistance with high creep strength required in the hot end or the low temperature corrosion high ductility required in the cooler end.

Generally, it is anticipated that the hot end (designed to operate above about 1500°F (816°C) can, for example, use MCrAlY coatings (with M being Ni and/or CO). Similarly, it is anticipated that the cooler end coatings be similar to the MCrAlY (with M being Fe or FeNi or combinations thereof).

Figure 4 shows typical ductility variations with temperature for coatings and nickel-based superalloys. The ductility of coating A is equal to or greater than the base metal alloys at temperatures above about 1350°F (732°C) and the ductility of coating B is equal to or greater than the ductility of the base metal alloys above about 1050°F (566°C). The corrosion resistance of coating A is greater than that of coating B above about 1400°F (760°C) while below about 1300°F (704°C) coating B has a corrosion resistance at least as good as that of coating A. Thus, the coating system of this invention provides improved protection against low coating ductility problems (above e.g. 1000°F (538°C)) and against corrosion problems.

Again, the transition zone which is coated with a mixture of the coatings is to be generally greater

than 0.5 inch (12.77 mm) in height. The location of the transition zone can vary with various coatings, but at lesat a portion of this transition zone will be in a portion of the blade which is designed to operate at a temperature of between 1250 and 1500°F (677 and 816°C). Preferably, at least a portion of the transition zone is to be at a part of the blade which is designed to operate at between 1300 and 1450°F (704 and 788°C) and most preferably as 1350°F (732°C).

Claims

1. A coated turbine rotor blade or nozzle guide vane for land-based or marine combustion turbines, said blade or vane having a hot end portion (10, 14) at least a portion of which is designed to operate at a -temperature in excess of 1500°F (816°C) a cooler end portion (12, 16) at least a portion of which is designed to operate at a temperature of less than 1250°F (677°C) and an intermediate portion at least a portion of which is designed to operate at between 1250°F and 1500°F (677°C and 816°C), characterized in that said blade or vane comprises a hot end portion (14) coated with a low creep-type coating which is resistant to high temperature oxidation, a cooler end portion (16) coated with a ductile-type coating which is resistant to sulfide corrosion, and an intermediate portion (18) which is coated with a mixture of said hot end coating and said cooler end coating.

2. A blade or vane as claimed in claim 1, characterized by a mixture of said hot end coating being applied over at least 0.5 inch (12.77 mm) of blade height.

3. A blade or vane as claimed in claim 2, characterized in that said cooler end coating is chosen from the group consisting of MCrAlY, where M is Fe or FeNi.

4. A blade or vane as claimed in claim 2 or 3, characterized in that said coatings are applied by plasma spray.

Patentansprüche

1. Eine beschichtete Turbinenrotorschaufel oder eine Düsen-Leitschaufel für Land- oder See-Verbrennungsturbinen, wobei die Rotorschaufel oder die Leitschaufel einen heißen Endteil (10, 14), von dem mindestens ein Abschnitt für einen Betrieb bei einer Temperatur von mehr als 1500°F (816°C) ausgelegt ist, einen kühleren Endteil (12, 16), von dem mindestens ein Abschnitt für einen Betrieb bei einer Temperatur von weniger als 1250°F (677°C) ausgelegt ist und einen Mittelteil aufweisen, von dem mindestens ein Abschnitt für einen Betrieb zwischen 1250°F und 1500°F (677°C und 816°C) ausgelegt ist, dadurch gekennzeichnet, daß die Rotorschaufel oder die Leitschaufel einen heißen Endabschnitt (14) mit einem Überzug, der ein geringes Kriechverhalten zeigt und gegen Hochtemperatur-Oxidation beständig ist, einen kühleren Endabschnitt (16) mit einem Überzug, der duktil und gegen Schwefel-Korrosion resistent ist, sowie einen Mittelabschnitt (18) aufweisen, der mit einer Mischung aus den Überzügen des heißen und des kühlen Abschnitts überzogen ist.

2. Eine Rotor- oder Leitschaufel nach Anspruch 1, dadurch gekennzeichnet, daß eine Mischung aus dem Überzug des heißen Endes über mindestens 0,5 Zoll (12,77 mm) der Höhe der Schaufel aufgetragen wird.

3. Eine Rotor- oder Leitschaufel nach Anspruch 2, dadurch gekennzeichnet, daß der Überzug für das kühlere Ende aus der Gruppe ausgewählt wird, die aus MCrALY besteht, wobei M für FE oder FeNi steht.

4. Eine Rotor- oder Leitschaufel nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß die Überzüge durch Plasmasprühren ausgebracht werden.

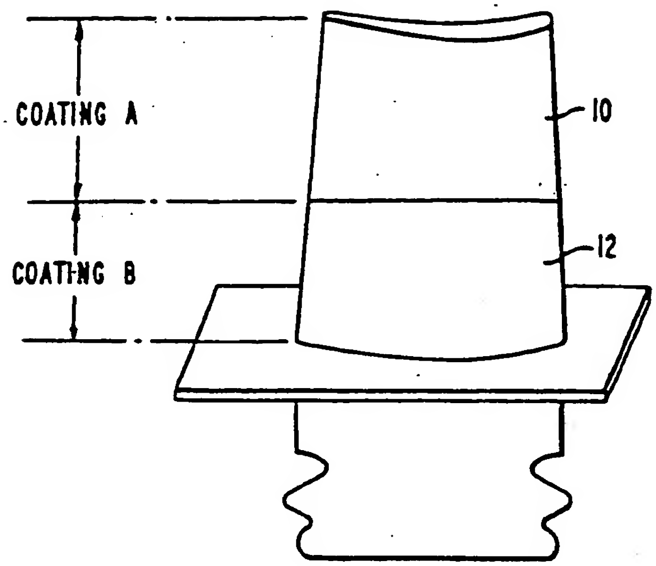
Revendications

1. Aube motrice revêtue de rotor de turbine ou aube directrice revêtue de diffuseur pour turbines terrestres ou marines à combustion, cette aube motrice ou aube directrice comprenant une zone d'extrémité très chaude (10, 14) dont une partie au moins est conçue pour travailler à une température supérieure à 816°C (1 500°F), une zone d'extrémité plus froide (12, 16) dont une partie au moins est prévue pour travailler à une température inférieure à 677°C (1 250°F), et une zone intermédiaire dont une partie au moins est étudiée pour travailler entre 677°C et 816°C (1 250°F et 1 500°F), caractérisée en ce que cette aube motrice ou cette aube directrice comprend une partie d'extrémité très chaude (14) sur laquelle est appliqué un revêtement à faible fluage et qui résiste à l'oyxdation à haute température, une partie d'extrémité plus froide (18) sur laquelle est appliqué un revêtement du type ductile et qui résiste à la corrosion par les sulfures, et une partie intermédiaire (18) sur laquelle est appliqué un mélange du revêtement de l'extrémité très chaude et du revêtement de l'extrémité plus froide.

2. Aube motrice ou aube directrice suivant la revendication 1, caractérisée en ce qu'un mélange du revêtement de l'extrémité très chaude est appliqué sur au moins 12,77 mm (0,5 pouce) de la hauteur de l'aube.

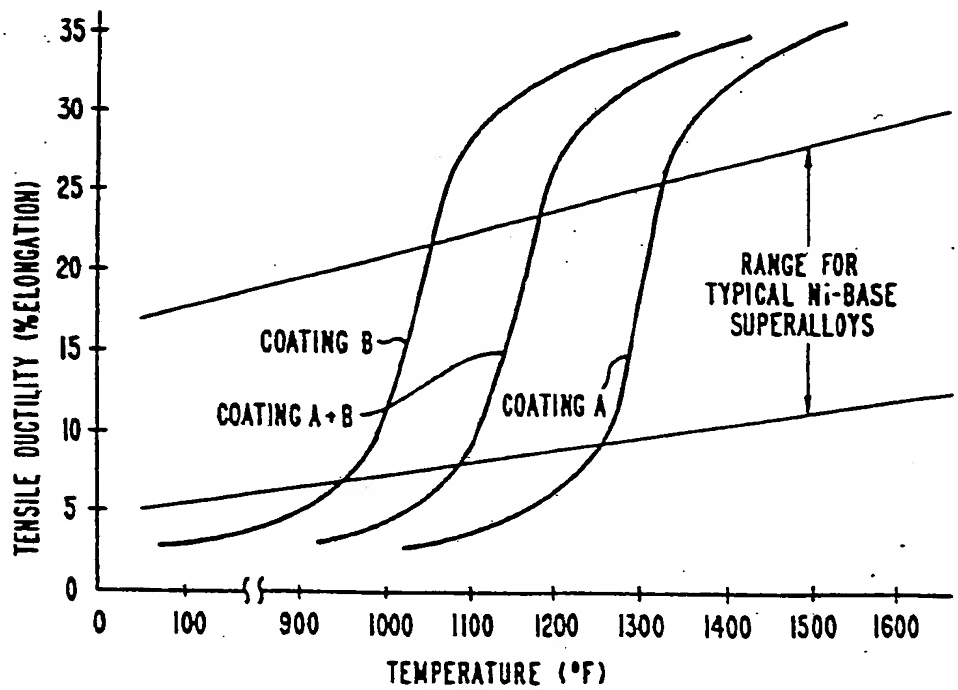
3. Aube motrice ou aube directrice suivant la revendication 2, caractérisée en ce que le revêtement de l'extrémité plus froide est choisi dans le groupe composé de MCrAlY, dans lequel M représente Fe ou FeNi.

4. Aube motrice ou aube directrice suivant la revendication 2 ou 3, caractérisée en ce que ces revêtements sont appliqués par un jet de plasma.



COATING A
COATING B
10
12

FIG. 1



TENSILE DUCTILITY (% ELONGATION)
35
30
25
20
15
10
5
0
0
100
900
1000
1100
1200
1300
1400
1500
1600
TEMPERATURE (°F)
COATING B
COATING A+B
COATING A
RANGE FOR TYPICAL Ni-BASE SUPERALLOYS

FIG. 4

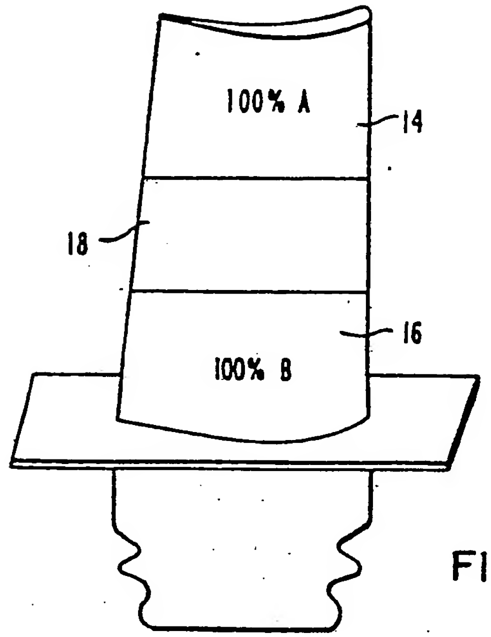

100% A
14
18
16
100% B

FIG. 2

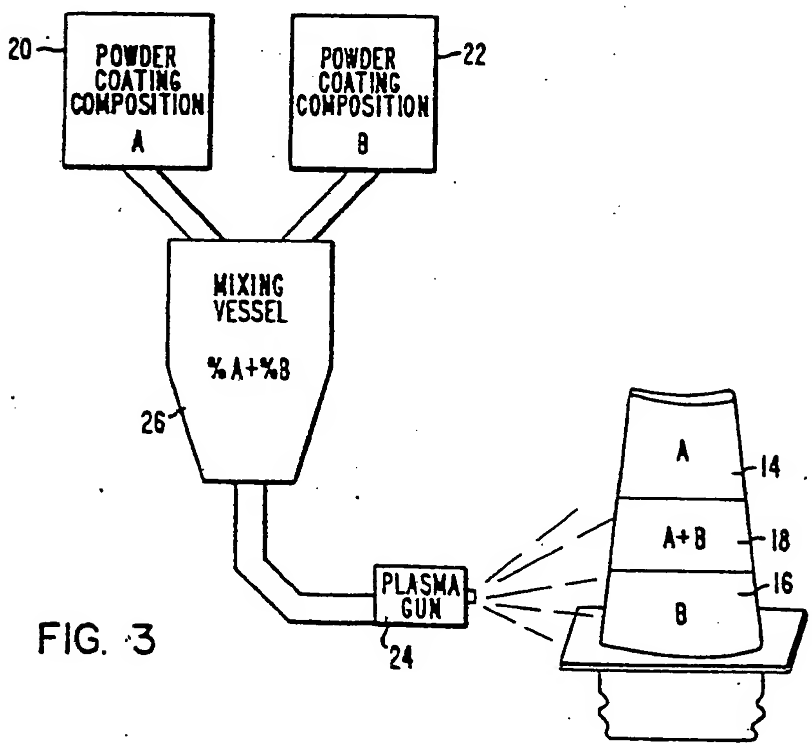

20
POWDER COATING COMPOSITION A
POWDER COATING COMPOSITION B
22
MIXING VESSEL
%A+%B
26
PLASMA GUN
24
A
14
A+B
18
16
B

FIG. 3